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ONTARIO
DEPARTMENT OF
EDUCATION

General and Advanced Levels of Instruction in Grade 13 General Science

JANUARY, 1966

As recommended by the General and Advanced Committee which conducted part of the Grade 13 studies, the suggested outlines listed below have been prepared at the direction of the Minister of Education by the Curriculum Division with the assistance of university and secondary school personnel. The outlines are to be considered as working papers rather than definitive courses. It is expected that they would be subject to further development and change if it is decided to submit them to field testing. They are being distributed to the universities and to the secondary schools for evaluation.

GA. 31	Accountancy and Secretarial	GA. 17E	General Science
GA. 13	Art	GA. 7	Geography
GA. 17B	Biology	GA. 15B	German
GA. 11	Classics	GA. 9	History
GA. 18	Chemistry	GA. 12	Mathematics
GA. 4	English	GA. 16	Music
GA. 46	français	GA. 17C	Physics
GA. 15A	French		

BROAD SUGGESTED OUTLINES OF PROPOSED GENERAL AND ADVANCED LEVELS OF STUDY IN GENERAL SCIENCE

ABSTRACT

These courses in General Science, at General and Advanced Levels, are designed to suit the needs of those who will remain laymen in science: the future businessmen, journalists, lawyers, politicians, teachers, and others who will study in the humanities. The courses lack the scope that would be needed for a student registering in the science-oriented programs of the universities and other post-secondary institutions.

The goals are two: to improve the student's literacy in science so that he may have a better understanding of the world about him, and to enhance his acquaintance with the methods of the working scientist.

Because broad unifying ideas and modern factual information are both important, the syllabus is framed along double lines. First, the specific facts in specific topics form the vehicle for something more general, and it is these facts he learns. But also, and at the same time, using this vehicle, the student learns how the scientist works and how science functions.

These are not survey courses. Since it is even less possible to attempt to cover the whole domain of science than any one scientific discipline, samplings are

made in several. The selections include significant topics, chosen because of their relation to economics, geography, history, language, mathematics and philosophy.

To provide for these courses in the secondary schools, two teachers with different backgrounds might work together throughout the year or by turns. The conventional laboratory-classroom might be supplemented by other facilities, such as a small tutorial room, a modestly equipped workshop and an outdoor area for field studies. The library will need many current scientific periodicals and reference books.

The successful operation of these courses will depend on finding teachers with broad roots in our culture, on providing encouragement and guidance during the experimental years, and on allowing time for the programs to develop in their own way. In many schools on past occasions science teachers have linked the great ideas of astronomy, biology, chemistry, geology and physics with the progress of mankind. Now in these general courses the student may be stimulated to search widely in order to learn how the mind of man interprets the natural world.

THE PROPOSED PROGRAM IN GENERAL SCIENCE

1 PREAMBLE

This is the report of a committee appointed to prepare the broad outlines for courses in General Science as a part of the General and Advanced Grade Thirteen Project.

The committee reviewed pertinent literature, consulted many individuals, and discussed the several drafts of the proposed courses widely. The members received advice from their colleagues in secondary schools, universities and colleges for teacher education, from scientists in industry, and from interested laymen. This assistance was invaluable.

The committee was presented with the challenge of designing wholly new courses to emphasize the essential unity of science, and yet provide for a sampling in

the several disciplines. It attempted to maintain in the courses a continuity of purpose, but also to allow the student to pursue significant topics at some length.

The committee agreed that the term "General Science" described the course adequately, but proved confusing when coupled with the accepted terms "General" and "Advanced". The committee, having no conviction on what name to recommend, made these six suggestions, and asked many persons for comment:

Connective Science	Natural Philosophy
Integrated Science	Science
Natural Science	Unified Science

Some support was received for each name, except for the first one listed.

This committee is convinced that a course at the General Level would meet a great need in education. The committee expects that the more difficult course at the Advanced Level would be less utilized.

The committee submits these outlines as tentative ones that need to be written in more detail, tried out with pilot classes, and then further modified.

2 THE STUDENT

These courses are intended to meet the needs of the student preparing for further education in an area other than the sciences. The committee has designed each syllabus to meet the needs of future lawyers, politicians, writers, businessmen, teachers, public servants — in essence, the science laymen. We appreciate the fact that such students are seeking only a literacy in science, and that they have no aspiration to become scientists nor to work in fields requiring considerable competence in science. What is possible is that a student who takes this course can acquire some understanding of the salient principles of science, and can develop a modern attitude of mind to science.

The committee considered, as requested, the desirability of the two levels as a core and a core-plus, but like the General and Advanced Committee, felt two separate courses would be more satisfactory. Whether a student registers in the Advanced or the General Level would seem to depend on the degree of his interest in science, the choice of his other subjects, and his future career.

It is recognized that students who intend to specialize in science or in a science-dependent field at university will elect one or more of the specialized courses. These students require science courses whose scope prepares them for further studies at university.

Indirectly, however, these courses in General Science will serve the interests of the scientist. For, to some degree at least, the non-scientist-to-be who takes either of these courses will be able to communicate with the

scientist-to-be. In a sense, the course forms a bridge between science and the other cultures.

3 GOALS

Our hope is to give the student a feeling for the kind of effort that is involved in science, and in so doing to develop his self-direction and power of independent attack on problems, as well as equipping him with some useful factual material. Yet we are only partially concerned with the data and the principles that are obtained from the scientific inquiry. Certainly the memorization of information has but small place in a program linked with the great ideas which have challenged man's mind.

Briefly, these courses are designed to enable the student to develop a measure of literacy in science, and empathy with the scientist. Scientific literacy gives a man sophistication in science so that he can read science and talk about scientific work. A sensitive empathy with the scientist and his way of life ensures that when the layman discusses science he does it reasonably and easily.

The literacy that we seek implies that the student should know some facts of science. He cannot know all the facts of science, for nearly one hundred thousand journals are currently publishing scientific papers. He cannot know something of everything, or everything about something. Both are impossible. Hermann Bondi has this answer:

"The best we can hope to say is that the student has been taken through some of the most striking, original and important ideas in the field, that he has learned the techniques required to appreciate these ideas, and that he has a mind that has been stretched and is ready to accept new and revolutionary ideas."

The student's empathy with the scientist derives its strength from knowing the manner in which scientists are creative. Just how do scientists work? Do they look on the world as something running according to the

laws of nature? Do they look on a complex universe as something which might be understood if it were observed more closely, and described more aptly? Why are laws framed? Why is the orderly progress of research interrupted at intervals by an upheaval of thought? What does it feel like to be doing research at some level? What are methods of mathematics, logic, and science that aid in discovery? By analogy Professor A. M. J. F. Michels has suggested what it is like to be a scientist:

“The author of a fine essay or book, an artist who produces a painting or statue, a theoretical physicist who discovers a new theory, an experimentalist who devises a new method . . . a technologist who invents a new engine, all perform acts of creation and all experience the same satisfaction of creativity.”

To feel the exultation and the frustration, the freedom and the discipline, the fellowship and the isolation which are part of the scientist's life may give the student as much insight into science as does an acquaintance with the great revolutionary ideas that have changed man's view of the universe and of himself.

4 METHODS

Although the syllabus points the way for the new courses, success depends on what actually happens when the teacher works with his students. He may find that his current teaching methods are quite suitable, or because the course presents science from a new viewpoint, he may adapt his procedures to it.

(a) Diversity—Either course may be expected to suit the individual students in the different localities better if the teaching is based on many avenues of approach. Some topics will be related to experiences in the laboratory, some to field work, some to the library and some to the tutorial room. Any single topic may suggest the use of the heuristic method, the historical approach, the case-history investigation, the structured laboratory search, or

the class discussion. More probably, the work will proceed by multiple approaches, at the choice of the teacher.

(b) Team Teaching—In many secondary schools, the science teachers have widely different backgrounds. If it were possible to have two or more teachers available as a team at all times, the course could be treated much more effectively. Outside speakers may be needed, and a short-term exchange of personnel with other nearby schools may perhaps be desirable. In these and other ways, more skilful teaching of a new and challenging course may be effected.

(c) Discovery—The direct involvement of the students in enquiry is basic to science, but the involvement must be genuine and not on a contrived or artificial basis. While the students will certainly not be breaking through the frontiers of knowledge, other newly developed courses have shown that students can share the excitement of discovering relationships for themselves. Many science teachers in the secondary schools have been following this philosophy for years; there is no reason why the practice cannot be extended.

(d) Reading—The search for information in the library should parallel the search in the laboratory and in the classroom. Individual reading assignments lead the students to look on books and periodicals as stores of experience. Accurate factual information is important in science. Some pooling of library services between schools may provide the wide resources so needed for a course that links the sciences and the humanities. To remind students that scientists read widely in other languages, some books and a few scientific periodicals might be provided in a second language. “Endeavour”, like some other periodicals, is published in several editions: English, French, German, Italian and Spanish.

- (e) **New Materials**—The committee has not studied the material resources that might be needed for the courses, but the members expect some modification of the present equipment inventory. For example, the camera may complement visual observations, and some recording devices may be those currently used in industrial research. Some of the new apparatus will be built in the school, some during the execution of student research projects. The assistance of a technician for this course and others is highly desirable. He might be ready to give technical aid during the whole day, as the laboratory will likely be used by individual students at their convenience, and on other occasions by the complete class. The students will likely be able to build some of their research project apparatus on a workbench in the laboratory, but the school shops could be available for making some other pieces.
- (f) **Time**—The Report of March 18, 1965, suggests that the working time of the student might be broken down into classroom time, laboratory time, and time for seminars, library research and special activities. Large blocks of time may be needed for longer experiments, field studies, or visits to museum, mine, or research establishments. Some flexibility is desirable, a flexibility more easily achieved in the Advanced Level course, which has an allotment of time twice that of the General Level course.
- (g) **Centres of Work** — Although the whole of the course-work can be accomplished in any laboratory-classroom, there is some advantage in spatial separation of work-centres. Six centres are listed below:

Library	Laboratory
Tutorial Room	Workshop
Classroom	Outdoor Laboratory

Students, on their own initiative, should select the special work-centre that their work currently demands. For example, consider the youth whose project is a month-by-month assessment of dust-fall, as a part of a larger plan to find the extent of air pollution in the school district. The boy might read in the school library, or find in municipal reports, that dust-fall has been measured in Hamilton since 1952; he might go to the workshop to fashion a dust-catching device; he might set it up in the open area reserved as an outdoor land-laboratory; he might weigh the accumulation of solid material in the laboratory; he might discuss the findings with his fellows in the tutorial room; and perhaps he might make a brief oral summary of his project in the science classroom. In the process of enquiry, he would work as a scientist works, in many places in many ways.

THE TWO COURSES

The proposed courses at General and Advanced Levels are somewhat different, the former emphasizing the characteristics of science, and the latter the role of the scientist. Both courses provide such topics for study as will enhance the student's literacy in science.

Since these two courses are designed for the person who does not intend to become a scientist, a freedom in the choice of topics is possible. There is no need for closely prescribing a syllabus to cover a subject, but there is a need for wide scope, and the courses do attempt to present significant highlights from each of the major disciplines of science. This means that the proposed outlines are framed as samplings into the disciplines, and that many important theories, principles and concepts are necessarily omitted.

Both courses assume that the student has a considerable background in science from his previous schooling. However, no common background is necessary. There is even some advantage when there are within a class students enrolled in a wide diversity of non-science subjects. Both courses rely on a wide experience in the humanities.

A feature of both courses is the presence of double headings, for example, "Atomic Structure: The Scientist as a Maker of Models". Here the second heading points to the great underlying idea, and the first to the vehicle that elucidates the idea. This duality extends also into what the student learns. He finds out factual data about the atom as Dalton saw it, and the later atoms of Bohr and Schrödinger. But he is also finding out that scientists devise many kinds of models so that they may understand and express what would otherwise be difficult. Perhaps the whole question of the reality of models emerges. As the teacher well knows, the student will remember how scientists use models long after he has forgotten the specific details of any atomic model he once studied. In both courses the facts exemplify the ideas.

OUTLINE OF THE GENERAL LEVEL COURSE

Part A THE NATURE OF SCIENCE

This segment of the general course is centered on the slow evolution of the scientist's ways of working.

Primitive men, and children, at first found explanations outside of science. The ancients long ago developed quite satisfactory theories for many phenomena. Later as phenomena were studied that seemed increasingly complex, the scientist tended to base his explanations on models of familiar things. Gradually the methods of the scientist took on a pattern, a basic pattern with infinite variations.

These patterns in science, though explicitly studied in Part A, are not limited to it. While the nature of science is discussed in this segment, it is exemplified in the two following segments. The ideas, that man can find reasons for things, that hypotheses are made to be tested, that theories are man-made and impermanent, that models are an aid to understanding, and that over the centuries scientists have developed useful methods, are all as valid ideas in the last topic of Part C as in the early ones. In one sense, this, The Nature of Science, pervades the whole course.

N.B. Some resources and activities are suggested below each listed topic. In a later syllabus, these items would be elaborated as a guide to the teacher.

1 CAUSE AND EXPLANATION: AN INSIGHT INTO THE MIND OF MAN.

In this unit the student finds that early man developed explanations for events quite outside of science. Similarly children, in attempting to explain such a phenomenon as nightfall, resort to realism, animism and artificialism, depending on their age. The meanings of *exploration* and *understanding* themselves need clarification.

(books, surveys, experiments)

2 THE DEVELOPMENT OF A THEORY: FINDING ORDER IN PLANETARY MOTION.

Man's changing picture of the universe from Ptolemy to Newton forms the vehicle in this unit for study of the scientific theory. Man has developed many theories. When any theory has failed to grow and encompass newly discovered data, it has had to be modified, or discarded.

3 THE SIGNIFICANCE OF THE MODEL: THE STRUCTURE OF THE ATOM.

From the Dalton atom to the differing atoms of Thomson, Rutherford, Bohr and Schrödinger, there is a sequence that illustrates the usefulness, but impermanence of models.

(experiments, books, reprints)

4 THE PATHS TO DISCOVERY: A BIOGRAPHY OF ONE SCIENTIST WHO WORKS ON A PROBLEM.

In this unit the students select a scientist such as Banting, Coleman, Fleming, Mendel, Tesla or Pupin, to learn how he found out what he did. The place of chance, logic, money, equipment, environment, and association with colleagues may become apparent. The extent to which a scientist follows intuitively or intentionally the ideal methods of science may emerge.

(materials largely depending on the choice of scientist)

5 THE STUDENT PROJECT: AN EXPERIENCE IN EXPERIMENTATION.

The student's individual project leads him to an experience where he more fully understands the methods of science. In this unit he has practice in choosing a topic and defining a problem. After making an hypothesis he devises an experiment with a care to proper control procedures. He may assemble or build apparatus, and make and analyse observations. In this project he attains a better understanding of the phenomenon he studies. The final paper that he writes will give him an insight into the amount of work represented in the voluminous literature of science. The one major project may be continued throughout the year, or a few minor projects take its place.

Part B CONTEMPORARY SCIENCE

In this section we are preparing a basis for decision. Throughout his life the student will be making decisions that call for a measure of scientific understanding. Rather than attempting to survey the whole field, this course samples in six currently significant areas. The teacher and students may select *four topics* from this segment.

1 RADIOACTIVITY: NUCLEAR PHENOMENA CROSSING THE DISCIPLINES.

This topic illustrates the essential unity of science. Basic nuclear research leads to geological and archaeological dating, tracer techniques in biology, power development, food preservation, and medical uses.

(experiments, papers)

2 THE LUNAR SURFACE: NEW TOOLS, NEW TECHNIQUES AND NEW METHODS, LEADING TO NEW KNOWLEDGE.

In this unit the student will find out the usefulness of periodicals, and of reprints from articles in periodicals. He may notice that scientific discovery often makes no regular predictable pro-

gress, but is dependent on economics, engineering, and politics.

(papers, maps, photographs and telescopic observation)

3 THE EVOLUTION OF LIVING FORMS: THE PLACE OF SPECULATION AND CONTROVERSY.

The origin of life and the diversity in plants and animals may be studied historically as well as in current context.

(case histories, papers, specimens, experiments)

4 POLYMERS: EXAMPLES OF APPLICATION OF SCIENCE.

The structure of chemical compounds, bonding, and molecular shapes lead to carbon chemistry and to polymers whose properties are custom-built.

(papers, experiments)

5 ECOLOGY IN THE LOCAL AREA: THE INTERDEPENDENCE OF LIVING THINGS.

A quantitative study of some plant and animal populations forms a background for decisions on productivity, conservation and pollution.

(field studies, experiments, periodicals)

6 GENETICS.

When an organism reproduces, how is information passed on to the offspring, making it possible for an accurate replica to be reproduced? In the past decade, scientists have come much closer to the answer.

(experiments with corn seedlings; microscope work; calculations)

Part C SCIENCE AND SOCIETY

Just as the boundaries between the fields of science are established by convention and convenience, so there are zones where the sciences meet the humanities. In these zones decisions are continually being made which are more fruitful if they are based on knowledge and executed with wisdom. The success of many great ventures depends on an understanding in science and a competence in the non-scientific fields.

The foregoing has indicated that this section premises a higher level of difficulty. The class and teacher should select *one or two* of the following topics. The topics should be treated in global fashion, in scholarly ways and as an exercise in current history.

- 1 TECHNOLOGY AND SCIENCE IN SPACE EXPLORATION.
The contributions of the technician and the technologist, the extent of a space venture, and the significance of the discoveries may be studied in this unit.
- 2 MAN'S CHANGING ENVIRONMENT.
A study of the background facts of food resources, energy resources, and ecological conditions allows the problems of population, pollution and conservation to be seen in perspective.
- 3 THE LIMITATIONS OF SCIENCE.
In this unit the student may meet the problems linked to the "explosion" of knowledge, find topics where no scientific methods have validity, or encounter the difficulties inherent in the making of measurements.
- 4 AUTOMATION AND FEEDBACK CONTROL.
In this unit it is recognized that machines are being adapted to attack the type of decision problems formerly reserved to men.
- 5 SCIENCE AND PHILOSOPHY.
This unit may serve as an example of one that investigates a topic from the viewpoint of two subject areas.

OUTLINE FOR THE ADVANCED LEVEL COURSE

Part A THE SCIENTIST AND HIS ACHIEVEMENTS

In this first segment, the student learns how the scientist works. The scientist is shown to be a person who observes, reflects, speculates, experiments, deliberates, makes decisions, and eventually publishes his findings. Secondly, in this segment, the student at the same time is being introduced to some of the most striking,

original and important ideas in science; he is learning the techniques required to appreciate these ideas; and is developing a mind stretched and ready to accept other new and revolutionary ideas. Thirdly, the student is discovering that scientists are a product of their times, and that the thoughts of the scientist are conditioned by their entire environment. Thus an approach through history and philosophy is almost essential.

In short, far from attempting to teach only the important principles and supporting data in a subject field, the teacher is leading the student to see that the scientist has a way of working, and that his potential achievement is dependent on the society in which he lives. The facts of science are important, but they are only one part of the scientific activity.

- 1 LIGHT, COLOUR AND VISION: THE SCIENTIST AS AN OBSERVER.
In this unit one learns that the process of investigating the world objectively does not come intuitively. The phenomena associated with "vision" form the vehicle for the study into how a scientist makes observations. Included would be the physiology of sight, and the psychological aspects describing how the mind perceives what the eye senses. Thus, early in the course the student is introduced to such important questions as, "What is the nature of *reality*?" and "What is meant by the term *explanation*?"
(laboratory experiments, reading, discussion)
- 2 THE DEVELOPMENT OF MAN'S PICTURE OF THE UNIVERSE: THE SCIENTIST AS A MAKER OF THEORIES.
In this unit the scientist is shown as one who attempts to correlate into a coherent structure the observations that he makes upon the natural world. Hypotheses are the conjectures that man makes; as more verifying evidence is gathered for any hypothesis, it attains the status of a theory. This theory may grow and encompass newly discovered data, or it may prove so inadequate that it must be modified.

The vehicle for these ideas is the study of the observed movements of the planets, stars and galaxies. From primitive anthropomorphic interpretations to the Ptolemaic theory, and to the Copernican revolution, the influence of the civilization in which the astronomer lives would be shown. The unit includes the contributions of Kepler, Galileo and Newton.

(use of telescope, ephemeris, photographs, models, books)

3 LIGHT WAVES AND PARTICLES: THE SCIENTIST AS AN EXPERIMENTER.

The experiment is probably the most valuable invention of the scientist. In this unit one learns how the need for an experiment emerges, and for the selected cases, how original apparatus was designed, observations were made and recorded, results analysed and conclusions stated. Some distinction between the theoretician and the experimentalist might be drawn.

The vehicle for these ideas is the history of theories of light. Although there were always non-conforming voices, considerable acceptance was early given to the Newtonian corpuscular theory. Inadequacies were always present, however, and the work of Young and Fresnel led to the acceptance of a wave theory of light. Fizeau's crucial experiment administered a premature death-blow to the corpuscular theory. The work of Einstein on the photo-electric effect, and the need to introduce the quantum for explaining the radiation distribution, re-instated it and led to a dilemma that revolutionized physical science.

(experiments, reading)

4 ATOMIC STRUCTURE: THE SCIENTIST AS A MAKER OF MODELS.

Scientists use models when the phenomena would otherwise be indescribable and incomprehensible. The new discoveries of science, especially the more significant ones, do not conform to their times and,

sometimes, are seemingly remote from common sense. If the discoverer can devise a model that incorporates his data, the new idea becomes more plausible and is more likely to be accepted. The more familiar the model, the more readily the new idea will be received.

While chemistry achieved its first unification from the hypotheses of atoms as individual, indivisible entities that combined with one another, the phenomena of electrochemistry, radioactivity, and spectroscopy greatly modified the theory. This unit follows the changing atomic theories up to the use of quantum numbers.

(laboratory and library work)

5 THE CELL: THE SCIENTIST AS AN INNOVATOR.

Progress in science often depends on the ability of the scientist to invent tools, and to develop techniques and methods. Sometimes instruments are gradually improved, but at other times a revolutionary change in design allows a great advance in what can be observed. The invention of the electron microscope is one example.

The study of the cell forms a vehicle to indicate the scientist's reliance on his equipment. Compared to the atom and the molecule, the cell is a unit of far greater size and complexity. In this part it is seen as a microcosm having a definite boundary within which constant chemical activity goes on.

(use of microscope, biological techniques, photomicrographs and electron photomicrographs, and current literature)

Part B CURRENT SCIENTIFIC THOUGHT AND PRACTICE

In this second segment the student comes as close to the "frontiers of science" as possible. He should realize that to become up-to-date in even one field of science is very difficult, partly because new ideas are expressed in technical style and have not yet been written in popular fashion, and partly because the fresh ideas have not yet become a part of the culture of the times.

In addition to the science of this part, the student may become aware of differing styles of exposition. Some scientists have been distinguished writers. Such periodicals as "Endeavour" and "Scientific American" provide much well-written material.

From topics like those listed below the teacher and class should select *three or four* that are of local importance, and that widen the interests of the students. The suggested topics are diverse so that the student will become familiar with some of the tools, techniques, and methods that modern scientists currently use in several disciplines.

*Ecology and Resource Management — The rise of ecology, the increased need for conservation of natural resources and for management of wild life, and the tremendous upsurge of popular interest in nature study have combined to send thousands of scientists into field studies. In this unit the concepts of species, taxonomic keys, succession, and biomes would be developed. Quantitative measurement will require a study of sampling procedures and some statistics.

(use of the outdoors as a laboratory, collecting apparatus and microscopes)

*Space Exploration — The mutually supporting resources of science and technology have made rapid progress possible. The students may study the principles underlying space vehicle propulsion and navigation, and trace some of the experiments that have been set for space probes such as Alouette.

(use of books, papers and recorded data)

*Limitations of Measurement — Einstein's theory of special relativity and Heisenberg's Uncertainty Principle are examples of ideas that have greatly changed older physical theories.

(use of the library)

*Evolution — Continuity of development might be studied from any one of three aspects: biological, paleontological or geological.

(using specimens, field studies, experiments, books and papers)

*Nuclear Energy — The contributions of economics, engineering, science and technology to this field form an example of the interdisciplinary foundations of modern life.

(using books, papers, movies, field trips and simple experiments)

*Storms — In this unit the student becomes aware of the energy balance associated with air circulation and with storms.

*Ore Bodies — In a mining community, the course might offer a unit dealing with exploration, mining, and metallurgy of the local ore, and the twin roles of science and technology.

*Electrochemistry — In this unit, the class might treat the topic from the viewpoints of theory, technology, and industry.

Part C THE SCIENTIFIC ENTERPRISE

Students taking specialized courses in science that lead to post-secondary education in science will encounter eventually the broad enterprises of scientists that extend beyond the classroom. In this third segment the non-specializing student who registers for *this* course meets the scientific community, a community serving all citizens.

The examples selected for each topic are suggestions only. Each teacher should be free to select the example most suited to illustrate the basic idea involved.

- 1 The international character of science: earthquakes, aurora, IGY;
- 2 the role of the scientific society: case history of one learned society;
- 3 communication between scientists: sampling of journals and published letters;
- 4 communications between scientists and the public: the scientist as an author, the journalist in science;

- 5 relation between basic and applied research: case history of an agricultural application of science;
- 6 technology and science: statistics of technologists and technicians working in various fields with scientists;
- 7 interdisciplinary nature of science: an example of research in biophysics, geophysics, biochemistry or any other similar subject area.

N.B. It is not intended that Part C should have a time allotment equal to the other parts. Rather it might be assigned a time more or less equal to any of the units in Part A.

Part D MAJOR PROJECT

Here is an opportunity for the student to develop himself in an area of his specific interest, and, incidentally, to play a role in planning the course for himself. Moreover, as he chooses his topic he is practising one of the responsibilities of the professional scientist.

The major projects should be selected by the students. When a draft of the proposal has been agreed upon by the teacher, the student should be able to work independently, except for occasional encouragement and consultation. The typical project will be one that requires inexpensive materials, can be pursued within a limited period of time, and is related to some section of the syllabus.

The project should reflect the student's own thoughts and involve his ingenuity. Much of the worth of the venture follows from the student's devising his own experimental procedures, and from the writing of the technical paper.

REFERENCE BOOKS

Baldwin, Ernest, *The Nature of Biochemistry*, Cambridge University Press, 1962.
 Butler, J. A., *Inside the Living Cell*, Basic Books, 1959.
 Chapman, L. J. & Putman, D. F., *The Physiography of Southern Ontario*, University of Toronto Press.
 Ford, K. W., *The World of Elementary Particles*, Blaisdell, 1963.

Gamow, George, *Matter, Earth and Sky*, Prentice-Hall, 1958.
 Gardiner, M., *Facts and Fallacies*, Dover, 1957.
 Glasstone, S., *Sourcebook in the Space Sciences*, Van Nostrand, 1965.
 Heisenberg, W., *Physics and Philosophy*, Harper, 1958.
 Hodgson, J. H., *Earthquakes and Earth Structure*, Prentice-Hall, 1964.
 Hogg, Margaret E., *A Biology of Man*, Heinemann, 1962.
 Kline, M., *Mathematics in Western Culture*, Oxford, 1963.
 Kuhn, T., *Structure of Scientific Revolutions*, University of Chicago, 1962.
 Laurendeau, M. & Pinard, A., *Causal Thinking in the Child*, International Universities Press, 1962.
 Laurendeau, M. & Pinard, A., *La pensée causale; étude génétique et expérimentale*, Montreal, Institut de recherches psychologiques, 1962.
 Lessing, P. L., *Understanding Chemistry*, Inter Science, 1959.
 Margenau, Henry, *Open Vistas*, Yale University Press, 1963.
 Munitz, M. K., *Theories of the Universe*, Free Press of Glencoe, 1957.
 Nagel, Ernest, *The Structure of Science*, Harcourt & Brace, 1961.
 Paul, John, *Cell Biology*, Heinemann, 1965.
 Peierls, R. E., *The Laws of Nature*, Scribners, 1956.
 Piaget, J., *La causalité physique chez l'enfant*, Librairie Felix Alcon, 1927.
 Piaget, J., *The Child's Conception of Physical Causality*, Littlefield, 1930.
 Rapport, S. & Wright, Helen, *Science: Method and Meaning*, New York University Press, 1963.
 Rogers, E., *Physics for the Inquiring Mind*, Princeton, 1960.
 Sankey, John, *Guide to Field Biology*, Longmans, 1958.
 Selye, Hans, *From Dream to Discovery*, McGraw-Hill, 1964.
 Shapley, H., *The View from a Distant Star*, Basic Books, 1963.
 Walker, M., *The Nature of Scientific Thought*, Prentice-Hall, 1963.
 Warner, W. E. & Benton, A. H., *Principles of Field Biology and Ecology*, McGraw-Hill, 1958.
 Woodburn, J. H. & Obourn, E. S., *Teaching the Pursuit of Science*, Collier-Macmillan, 1965.

PERIODICALS

The Advancement of Science, published monthly by the British Association for the Advancement of Science, 3 Sanctuary Buildings, 20 Great Smith Street, London, S.W.1, England.

Discovery, published monthly at Mercury House, 109-119 Waterloo Road, London, S.E.1, England.

Endeavour, published quarterly at Endeavour, South Block, Thames House, Millbank, London S.W.1, England.

Le Jeune Scientifique, published eight times a year, Case Postale 6060, Montreal 3, P.Q.

New Scientist, published weekly from Cromwell House, Fulwood Place, High Holborn, London W.C.1, England.

Science, published weekly by the American Association for the Advancement of Science, 1515 Massachusetts Avenue N.W., Washington, D.C. 20005.

Science Newsletter, published weekly by Science Service Inc., 1719 N Street, N.W., Washington D.C. 20036.

Scientific American, published monthly by Scientific American Inc., 415 Madison Avenue, New York, N.Y. 10017.

